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PAPER  
ON  
RAILWAY GAUGES.

BY  
R. F. FAIRLIE.

READ BEFORE THE BRITISH ASSOCIATION AT EDINBURGH,  
SESSION 1871.

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## RAILWAY GAUGES.

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I HAD the honour last year, of reading before this Association a paper upon "The Gauge for the Railways of the Future," in which I pointed out the capacities of narrow gauge lines, and showed how unfavourably our own railway system, as at present worked, contrasts with such lines when properly handled. The great truths I then put forward were too startling to be received without some degree of ridicule and incredulity; and although I announced them in the full conviction that sooner or later they would be fully acknowledged, I was then little prepared for the rapidity with which that acknowledgment has come.

The report of the Imperial Russian Commission upon the Festiniog Railway, produced a similar inquiry on the part of the Indian Government. I had once more the satisfaction of attending a Royal Commission, appointed to investigate the question of narrow gauge; and the results obtained on the second occasion were as satisfactory as those on the first.

In Russia, at the instance of His Excellency Count Bobrinskoy, His Imperial Majesty the Emperor commanded a line of narrow gauge railway to be at once commenced, and a number of my engines to be constructed, in order that the accuracy of all I had asserted on the subject, and had shown to the Commission upon the Festiniog Railway, might be proved upon a more extended scale; and that the exact value of a narrow gauge system, for national service, might be ascertained by the fullest tests of experience.

The Association will, perhaps, pardon a brief digression, while I here place on record, as a matter of history, the eminent services rendered to the cause of narrow gauge extension by the Russian Commission, and also by Mr. Spooner, the engineer and manager of the

**Festiniog Railway.** This little line, of only 1 ft. 11½ in. gauge, was originally constructed for horse traffic; but was worked after a time by small locomotive engines, resembling, in everything but dimensions, those in common use in England. As thus worked, the traffic outgrew the carrying capacity of the line; and powers to construct a second track were actually obtained. At this conjuncture, Mr. Spooner had the sagacity to perceive the advantage that would accrue from the employment of my system of traction, of which he had read, and the determination to carry out his perception to a practical issue. I constructed for him the now well-known "Little Wonder" locomotive, and thus gave him, on his single line, two-and-a-half times the carrying capacity that he had possessed before. The second track was thus rendered unnecessary, and it has never been made. In the application of all novelties there must ever be risks of failure from unforeseen causes, and hence many, even when they recognise a truth, shrink from the responsibility of being the first to carry it into practice. The acceptance of this responsibility by Mr. Spooner, the opportunities that he thus afforded me of proving the working value of my principles, and the facilities for inspection and experiment that he has since courteously allowed, all fairly entitle him to be considered the father, as his tiny railway has certainly been the cradle, of the narrow gauge system of the future.

The next step was made by the Russian Commission. It would be difficult for me to do justice to the infinite care and pains with which Count Bobrinskoy, the President of that Commission, investigated every detail before arriving at his conclusion, or to the earnestness with which he afterwards pushed this conclusion to its legitimate results. In Russia, as in other countries, there are men whose interests or whose prejudices lead them to cling to existing systems, and the opposition which proceeded from such persons could only have been overcome by the strength of clear convictions, of unsullied integrity, and of indomitable resolution. Count Bobrinskoy was worthily assisted in his novel and important duty by the other members of the Commission, among whom I may name M. B. Saloff, Professor at the Technical School of Engineering, St. Petersburg; M. von Desen, now resident engineer in charge of the works; and M. Schoubersky, in charge

of the rolling stock of the Imperial Livny Railway. To these gentlemen the entire civilised world owes a deep debt of gratitude. The line which was constructed and equipped in accordance with their report has now for several months been in operation. The results of its working establish all that I claimed for the narrow gauge; and the final official trials that will take place this month will determine the general adoption of the 3 ft. 6 in. gauge in Russia, together with the employment of my locomotives, *without which the value of the narrow gauge at once sinks into comparative insignificance*. This rapid action is due to the promptness with which His Imperial Majesty of Russia appreciates progress, to his freedom from prejudice, and to the fact that I have never advanced anything which I have not been able to prove.

In India, although I believe ground has not yet been broken, a metre gauge has been decreed for general introduction; and the strongest advocates for the retention of the 5 ft. 6 in. gauge have been entirely defeated.

In Australia, Tasmania, and New Zealand, narrow gauge railways have been undertaken, and will be built as fast as means that have been straitened and opinions that have been prejudiced will permit.

In South America to a great extent, and in North America—I speak of the United States—to a marvellous degree, the reform I have so long, and at last so successfully, advocated, is making way with an astonishing rapidity. Some 2000 miles of narrow gauge line are under construction; the great Denver and Rio Grande Railway, 850 miles in length, is being built upon the gauge I have made specially my own; and I may mention that this width of 3 ft. was decided upon by the President and principal officers of the Company after considerable investigation of the principles of my system recommended to their consideration by Mr. George Allan, C.E., who, at an early period, became strongly convinced of its advantages. A great transcontinental railway from the East to the Pacific is being organised, which, it is expected, will also be on the new narrow gauge. California is building similar lines; the Western States and Territories—pastoral, agricultural, and mineral—are building them; Massachusetts, already covered with a network of ordinary gauge railways, is legislating for them;

and many others of the Eastern States are earnestly considering the advisability of their immediate construction.

As little as yourselves could I have last year imagined that all this progress would have been made in less than twelve months. At that time I was discouraged on almost all sides; I was hampered by the weight of prejudice and of opposition of every kind; but knowing I was right—knowing that the work I had in hand was one which would benefit the whole of the civilised world—knowing that, could I once produce conviction, there need be no country, however poor, that could not be supplied, no distance, however great, that could not be traversed by profitable railways, I persevered, and to-day I find that my efforts have been crowned with a great and substantial success. Need I say that I appreciate this victory, counting the past pains as nothing, and being still more anxious to continue advocating the truth.

But it is only due to this Association that I should state how much of my success I owe to its influence, and to the weight thus added to my now celebrated paper on "The Gauge for the Railways of the Future." To that paper I attribute a large proportion of the extraordinary activity that I have described. Stamped with the approval of this Association, the paper has circulated in all countries, and has been translated into all European languages, including those which have been naturalised in South America. It has formed the text for innumerable discussions; it is almost daily quoted in the journals of the United States; and it has excited the most lively interest among the railway engineers of that country, where existing railway management shows results still more discouraging than those which are obtained in England. The British Association, therefore, more than any other public body, has helped forward a vast reform, and gratefully feeling this, I am encouraged to come here again on this occasion.

It is not long since, that to doubt established gauge was professional heresy. A type to which an accident had given birth, had come in course of time to be considered perfect; it was a superstition quickened into a religion. By degrees, after scores of thousands of miles of railway had been built, and hundreds of millions of pounds expended, it began to be seen that there was something still to be desired, and that it was ruinous to make railways for the service of

remote districts yielding but small traffic, or in countries whose limited means and commerce could not justify large expenditure. By this time the great outlay which attended the labours of the earliest engineers—the outlay involved by heavy works to gain easy gradients—had been somewhat reduced, and with improved locomotive practice, steeper gradients and sharper curves became possible. Then came the very recent modification of making essentially light lines upon the standard gauge, conforming as much as possible to the natural contour—*surface lines*, as I was the first to name them in 1864. By adopting them the cost of construction was greatly reduced, and was brought somewhat more into proportion with the revenue to be derived.

But these improvements were but improvements upon a bad type, and real reform could not be effected whilst the width of gauge remained, while the rolling stock continued unaltered, and the locomotive rested unmodified.

Meanwhile, the history of railway construction in England was slowly repeating itself, even in an exaggerated form, abroad, and particularly in our colonies, where the primitive types were perpetuated by the pupils of the old school of engineers. And here I may remark that the difficulties encountered in this country in railway reform have been faithfully repeated in our colonies—an illustration of cause and effect.

Gradually it became known that the ruinous practice of English engineers in Norway had forced the government of that country to adopt an entirely new type, *after the intermediate stage of light standard gauge railways had been largely tested and abandoned*, and that for the first time a national narrow-gauge system was established. But this was done so quietly, and information filtered so slowly from that isolated country, that until quite recently only a few have known of the change, and still fewer have known, or have cared to inquire, about the practice followed or the results obtained.

Of course, exceptional and independent lines of very narrow gauge, established almost universally for mineral traffic, have existed for many years; but these, with the exception of the Festiniog Railway, do not enter into the question; on the contrary, indeed, their small traffic capacities, as worked, have served the opponents of narrow gauge as arguments against innovation.



So matters stood when I, having convinced myself of the monstrous errors which cripple our standard railway system, and having learnt the capabilities of narrow gauge—which are yet scarcely understood even by the engineers who are advocating and constructing them—so matters stood when I first devoted myself to the effort of promoting the general introduction of narrow-gauge lines, and had the audacity to set myself up in opposition to long-established and deeply-rooted principles. At first the utmost concession I could obtain—a concession granted but by a few—was that for new countries, where railways did not exist, or for poor countries, where traffic was light and uncertain, a narrow-gauge system might be adopted with some amount of advantage; but that its capacity and consequent utility were proportioned to its gauge; and that hence, as a natural consequence, not only must such lines as I recommended be located in districts where only a very small business actually existed, but where also the prospects of its increase were extremely remote. I knew the error of this opinion, for I knew the actual capacity of narrow-gauge railways under proper management; therefore I was encouraged to persevere until, as the circle of conviction widened, I was enabled to put my views to the test of actual and wide experience, and to stir into life the radical reform which to-day is spreading on every side, and which shall before long become general.

I showed you last year how, upon a railway costing one-third less than a line of an ordinary gauge, I could with equal despatch carry such a traffic as that of the London and North-Western Railway, with a saving of three-fifths of the dead load carried; and how in so doing I could effect a corresponding reduction in engine power, and consequently in cost of fuel, of rolling stock, of engine repairs, and of maintenance of permanent way. All this could be effected at a speed at least equal to the present speed of freight trains for the goods traffic, and at 35 miles an hour for the passenger traffic; a rate which is but little below the average of the mileage made by fast passenger trains in this country. We are so accustomed to the present condition of things—or, perhaps, we are so ignorant of the real elements of railway economy—that it is difficult to believe this great reform possible, but belief was more difficult a year ago than it has since

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become, now that all my statements have been proved to be incontrovertibly true. The question, however, is one of such radical importance, that I may once more devote a few words to its elucidation.

On the London and North-Western Railway the average practice is to employ 7 tons of wagon to carry 1 ton of goods, but I assume the proportion of dead weight to be only four to one, in order to make out as favourable a case as possible. The average weight of a goods train on the London and North-Western Railway is 250 tons; composed, in the proportions I have mentioned, of 50 tons of freight to 200 tons of rolling stock. (See diagram.) On the Livny (New Russian), 3 ft. 6 in. Railway, on the other hand, the average gross weight of trains is 354 tons, or 104 tons more than that of the London and North-Western, while the dead weight is only 94 tons. This proportion is also shown on the diagram. To carry this paying load of 260 tons on the London and North-Western, 1040 tons of wagons would be employed, or more than eleven times the weight required by my system. In all my arguments, I of course deal with general goods' traffic only, exclusive of minerals. It may be urged against this comparison that the more favourable traffic conditions of the Livny Railway help the results; but it is sufficient to reply, first, that with the reduced gauge reduced weight of wagons in proportion to capacity is feasible; next, that the smaller wagon capacity is essential to economy; and third, that while rolling stock of the smaller class is certain to be loaded more nearly to its ultimate limits, the difference between the maximum load, and the absolute loads obtained in practice, are attended with none of the excessive cost inevitable on a 4 ft. 8½ in. gauge. I would here call your attention to a most important fact in connexion with railway goods' traffic. The average load of merchandise carried by each wagon in this country is considerably less than 1 ton. Experience has proved that the exigencies of traffic in this country have settled this average, yet wagons of four times this capacity must nevertheless be provided. This fact of itself is sufficient to show that so broad a gauge as the standard one is very excessive. With a narrow gauge this evil may be prevented, and if a higher average per wagon could not be attained, at least a far lower proportion of dead weight would result. This I have endeavoured to make apparent in the diagrams, which

show the average proportions of dead to paying weight on the 4 ft. 8½ in. gauge, and on the 3 ft. gauge; and I have also placed the load carried as the average by the standard gauge upon a train running on a 3 ft. gauge, the varying proportions being well expressed by contrasted colours. The great economy in working, brought about by the causes enumerated above, would react upon railway business, and in increasing it would certainly raise the wagon average, *because the cost of carriage would be so much reduced.*

I think you will agree with me that I am no visionary, but have always spoken within the mark, making my position sure as I advanced, and asserting nothing that I could not prove in actual practice. I have obtained, by the development of my system, results very closely approximating to those I stated last year—namely, three to one of paying to dead load, and I know that this proportion can and will be reached when my views are fully carried out, when a Fairlie gauge is worked with Fairlie locomotives and stock; while by no other system in existence can such results be obtained.

In the report of the Royal Railways' Commission, published in 1867, the following pregnant conclusions were arrived at from the opinions of the principal engineers and railway managers in this country: "*The only way in which an increased receipt in proportion to the cost of running the trains can be anticipated, is in carrying a larger number of passengers in proportion to the number of passenger carriages in the train, and running the goods' trucks full instead of partially full; or, in other words, obtaining a greater amount of work out of the engines and carriages than at present. But this means that the passenger trains would be less frequent and more crowded; that the passengers going on to branch lines would have to change carriages more frequently; and that goods would have to be retained until full truck-loads were made up, which would result in a slower delivery of goods.*"

So that, as the necessities of traffic enforce frequent passenger trains, three or four times the necessary weight of carriages must be provided, and as goods cannot be detained until trucks are fully loaded, it follows that universal extravagance is inseparable from the present system. Railway managers, who are of course thoroughly

conversant with the subject, agree that our existing railways are at present being worked to the best advantage. If so, it cannot be doubted that there is a grave blunder somewhere; and if this blunder is not to be discovered in management we must seek for it in construction, and there we shall find it. We shall find that railways of the existing gauge will labour under disadvantages for all time; they will remain oppressed by the curse of dead weight, an evil from which they can by no means be relieved; dead weight in their rolling stock for passengers, one ton of which requires thirty tons to convey it; dead weight in their rolling stock for freight, which can never be more than one quarter fully loaded, and dead weight in their locomotives, ill applied for obtaining useful results, but always destructive to the permanent way.

Nor does increase of traffic upon a great standard-railway system tend to reduce this evil; if it did, the London and North-Western Railway would not at the present time be expending enormous sums in doubling their permanent way. Experience shows that increased traffic does not diminish averages of weight; for the fact that these averages were larger twenty years ago than they are at present, although the traffic had not then reached half its present dimensions, was simply because the wagons then averaged about a ton less in weight. With a doubled business, each wagon does not carry twice the average amount that it carried twenty years ago; but twice the number of wagons then employed carry each their usual complement of a single ton. There is, therefore, no escape from the conclusion that the existing proportion of dead weight to paying weight upon a 4 ft. 8½ in. railway cannot be reduced, so long as the condition of things exist which guided the Railway Commission to its conclusions, but that it must remain a fixed quantity independent of increase of business on the line.

I think no more striking illustration of the error of our present system can be conceived than is afforded by the daily practice of a magnificent Company like the London and North-Western Railway; who, at the present moment, be it remembered, have commenced to double the width of their road through press of business; yet who are sending out daily, and daily receiving, at Euston-square, some 4400 passengers, in carriages which contain sitting accommodation for

13,500; and who carry their enormous freight in increments, averaging less than 1 ton, in wagons having six times that capacity. Imagine the amount of capital sunk before this result was obtained! Conceive the waste of engine-power, the wear and tear of rolling stock, the destruction of permanent way, the cost of staff, all entailed by this curse of dead weight; and then imagine how easily all this unmechanical and unbusiness-like state of affairs might have been prevented by the simple adoption of a suitable rolling stock running on a suitable gauge! I am not for a moment advocating any radical change in our English railway system; that system has out-grown the season of radical reform, and we must make the best of it as it is; but I seek to prevent the repetition elsewhere of mistakes that have been so costly here. I want to prevent the unnecessary extension of a system that is palpably false, but which is not on that account the less strongly defended and protected.

That our great error was known some years since to all thinking engineers, is shown by the quotation I just now made; Mr. G. P. Bidder stated before the Royal Commission: "*That great economy may yet be obtained in the transport of minerals over long distances by means of railways laid out under conditions admitting of very long trains being run.*" In this statement I find the very essence of the question at issue between myself and all conservative engineers; I find the necessity for reform acknowledged, and the means of attaining it hinted at by my warmest opponent. Except that his views did not extend to passengers and goods, but were confined simply to the transport of mineral traffic, we have a complete statement of the problem which I have brought successfully to a solution. The requirements which Mr. Bidder hinted at generally, I have worked out in detail, and have extensively reduced to practice, with results that show his judgment to have been sound as far as it went. The conditions under which a railway should be laid out to meet these requirements are clearly not those which rule the present system; ample experience proves the contrary, showing that no line, however full of business, can be worked to its full capacity. We are led, then, unmistakably, to a narrow gauge, to the adoption of passenger carriages which shall be filled, of wagons which shall be almost

fully loaded, and of weight which shall bear a reasonable proportion to their capacity, and we are led to the adoption of very long trains and powerful engines. Considering the date of Mr. Bidder's opinions, they could not have been put more clearly or more concisely.

To a certain extent, but in a very limited and imperfect degree, experiments were made in the direction indicated—faint foreshadowings of the practice now being so widely introduced—by an attempt to convey extremely heavy trains by means of an auxiliary pair of cylinders placed under the tender of the engine and receiving steam from the boiler; the idea being to utilise all the available weight of engine and tender for adhesion. In running expenses, the results of these trials were very satisfactory, showing a large reduction of cost in carrying the heavier load. There were many reasons why this arrangement should prove unsatisfactory, but I quote the results obtained, because they will not be called in question, and because, if so much economy could be obtained by such a contrivance as the steam tender, I may at least claim proportionately advantageous results for the system of which this was an indication.

Thus, with an ordinary engine, the cost of conveying a load of 210 tons was 20d. per mile, whilst the cost of conveying a load of 310 tons by the aid of the steam tender was only 23d. per mile. It is obvious that no such saving as this could have been effected had two independent engines been employed upon the same duty. The results clearly prove that a large saving can be effected by increased engine power and greater loads; but, as I have already pointed out, this economy cannot be realised on railways of the standard gauge: but on the many thousand miles of narrow-gauge railways that will before many years be constructed, the true system of economical working, developed by me, will not only be possible, but will be universally acknowledged and adopted.

It would seem a very simple and self-evident fact that the means of conveyance should be fairly proportioned to the amount to be conveyed, and yet I have been labouring for years to make people understand this. One would think it would be sufficient to point out, to countries contemplating the construction or the great extension of railways, and looking to England and English practice as a model, that the best

labours of our engineers, after thirty years' experience, have given us a railway system on which it is necessary to have 4 tons of wagon for every ton of goods, and from 10 to 30 tons of carriages (see the diagram) for every ton of passengers. And indeed abroad it is pretty widely understood that it can only be on a narrow-gauge railway that a full measure of usefulness can be obtained, and a proper proportion between paying and non-paying load can be secured;—this is because the amount of engine power being unlimited, better paying trains can be carried on the narrow than on the broad gauge; the difference arising from the fact that the dead weight required for the transport of passengers and goods is reduced in the manner shown by practice and indicated in the diagram. The reform is effected by the adoption of a suitable rolling stock, in which dead weight is kept down by the smallness of the gauge, but in which ample capacity is obtained. Such carriages and wagons exactly meet the difficulty which is one of the great causes of dead weight on a 4 ft. 8½ in. gauge—namely, the necessity of transmitting passengers and goods, whenever practicable, to their destination without change of vehicles. With the small carriages and wagons, the expense attending this proceeding is reduced to the lowest possible cost, because, though vehicles of appropriate capacity can be employed, and each can be loaded almost to its full complement of passengers or goods, carriages half or two-thirds empty would never form necessary accompaniments to a train; and even if it were not possible in practice to place a larger share of the load in each vehicle than the present average, we should have wagons of 5 tons capacity weighing 1½ tons, instead of others weighing 4 tons to carry the 1 ton average.

This capability of subdivision of traffic is one of the most important advantages which the narrow gauge offers; it involves the leading principle in railway economy, but it is an economy which I have shown—and I am borne out by all the weight of the evidence given before the Railway Commission—to be impossible on the broad gauge.

But it must be remembered—and this is a point not understood by some of the strongest advocates of narrow gauge—that *such lines are of but little avail, unless they are provided with suitable locomotive power.* If a line is made in all respects a miniature copy of a broad-gauge rail-

way, with miniature rolling stock and miniature engines, *its utility decreases, and its working capacity goes down, but its working expenses go up.* In illustration of this I may quote the results of Norwegian practice, where one of the narrow-gauge lines, carrying only a very small traffic as compared with that conveyed upon a broad gauge in the same country, shows its expenses to be out of all proportion; while the percentages of the expenses to the receipts vary from 65.47 to 103.5 on the various narrow-gauge lines now built in Norway, a result that cannot be considered favourable.

If we look at the capacity of the engines on these railways, we shall see that they are capable of drawing, besides their own weight, 83 tons, 55 tons, and 84 tons respectively, up gradients of 1 in 70, 1 in 42, and 1 in 60, and it is worth noting that the proportion of working expenses to receipts *decreases as the power of the engine increases.* Although many other causes besides those of mere locomotive expenditure step in to interfere with results, the regular proportion is, I think, too clearly marked to be independent of this most important question. The capacities of the Norwegian stock and the maximum trains conveyed by the engines are shown in the diagram.

I refer again for a moment to the results obtained by the employment of the steam tender for dragging great loads. Mr. Sturrock found that he could, by adding a pair of steam cylinders to the tender of a locomotive, convey trains weighing one-half as much again as the maximum load carried by ordinary engines, with an extra expenditure of about 15 per cent.; and a train of any given weight can be conveyed for from 64 to 70 per cent. of the cost of such a train divided into two equal parts, which means a saving in the locomotive accounts of from 30 to 36 per cent. It is argued against me that an engine of my system is no more useful or profitable than two engines coupled together. My experiences prove the contrary; so far as they go, the results with Mr. Sturrock's contrivance bear me out, and so do the results obtained by the working of MM. Meyer's engines (adapted from my own) in France.

If such a system as that which I recommend had been introduced into Norway, it is needless to point out that a considerable modification of the balance-sheet would have been the result.



To sum up, then, the requirements necessary for making a narrow-gauge railway perfectly efficient, we must have light, small stock, easily handled, and very powerful engines, capable of drawing heavy loads. The experience of the present year entirely bears out this assertion. We need only turn to the 3 ft. 6 in. Livny Railway in Russia, carrying regularly its 354 tons of train exclusive of engine, a duty accomplished by one Fairlie locomotive without distress to the permanent way, and up gradients, some of which are 1 in 80, of 4 or 5 miles in length, and with an economy shadowed forth long since by the crude appliances that were tried with a vague hope of achieving a similar result.

Again, as already stated, the introduction of the same system on the Festiniog Railway avoided the necessity of doubling the line of rails (a work which was actually commenced so far as preliminaries were concerned), by more than doubling the utility of the single pair. The diagrams show the change very strikingly, the one indicating the daily duty of the "Little Wonder," the other the similar duty of the ordinary engines of rather more than half the weight.

It now remains to point out as briefly as possible the circumstances that have led me to adopt a 3 ft. gauge, and to recommend that width for general introduction.

Experience has shown that 3 ft. 6 in. can be made a highly economical and efficient width, but it does not by any means follow that it is the most serviceable and most efficient, any more than it follows that the accidental 4 ft. 8½ in. was all that could be desired, even though an Act of Parliament had made it an article of belief.

On the contrary, as our knowledge and experience increase, we are enabled to approach more and more nearly to that happy mean, on either side of which is error. While, on the one hand, there is every necessity for obtaining such a gauge as will afford a good and useful width of vehicles, on the other it is necessary to avoid such narrow limits as would necessitate the introduction of too great overhang on each side of the rails. The 3 ft. gauge appears to me to comply with all the necessary conditions better than any other, and it is from no mere theorising that I lend all the influence I have towards its adoption. There is a certain amount of saving in first cost as compared

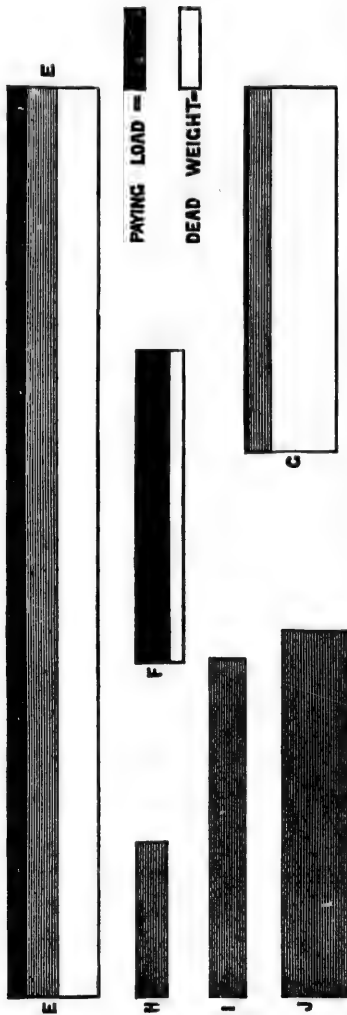
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DIAGRAMS SHOWING PROPORTIONS OF DEAD WEIGHT TO PAYING LOAD IN RAILWAY ROLLING STOCK.

## EXPLANATION OF THE DIAGRAMS.

THE diagrams on the opposite page represent various proportions between dead weight and paying load, on Railway Rolling Stock, as follows :

**A** shows the average load carried in daily practice by the Fairlie engine "Little Wonder" over the Festiniog Railway, 1 ft. 11½ in. gauge, the average up grade being 1 in 92. The engine weighs 19½ tons, the weight of load is over 107 tons, and the proportion of paying to non-paying load is 3 to 1.

**B** shows the average daily working of the ordinary engine, weighing 10 tons. The load carried is a little in excess of 43 tons.

[The above diagrams show very clearly the capacities of the Festiniog Railway after and before the adoption of the Fairlie engines on it.]

**C** shows the maximum load of 120 tons carried by the most powerful engines on the 3 ft. 6 in. Norwegian Railway up gradients of 1 in 90. The proportion of paying to dead weight is 1.6 to 1.

**D** represents the daily working of the freight train of The Imperial (Russian) Livny Railway, 3 ft. 6 in. gauge, up gradients of 1 in 80. The gross load conveyed (exclusive of engine) is 354 tons, of which 260 tons are paying weight. The engine weighs 42 tons, and the proportion of paying and non-paying loads is 2.78 to 1.

**E** represents the actual ratio between dead and paying loads conveyed in a 250-ton goods' train on the 4 ft. 8½ in. gauge; the lighter tint indicating the maximum capacity of the stock, giving 1.8 to 1 of paying to dead weight.

**F** shows the weight of a train on the 3 ft. gauge carrying the same paying load, 50 tons, as that conveyed by the wagons on the 4 ft. 8½ in. gauge, as shown in the previous diagram.

**G** is a diagram showing the existing ratio, between dead and paying weight, on passengers' train, 4 ft. 8½ in. gauge, as well as its maximum capacity, being 30 to 1 and 3.3 to 1 respectively.

**J I H** are diagrams showing the comparative dead weights of trains on the 4 ft. 8½ in., 3 ft. 6 in., and 3 ft. gauges respectively, employed to carry 50 tons of paying load, every wagon of each train being loaded up to the present average weight of 1 ton per wagon.



with the 3 ft. 6 in., not a large amount, but worth considering. This, however, I leave out of the discussion for the present. The all-important matters are to place upon the rails a thoroughly efficient stock that shall possess a maximum of capacity and a minimum of weight, and to supply engine power under the most economical circumstances, and I hold it to be easier to accomplish these objects on the 3 ft. gauge than upon any other.

I am led to this conclusion both by a comparison of the actual work done on the railways of the 3 ft. 6 in. gauge, with that which can be accomplished with the 3 ft. gauge, and because, having in view the practical requirements of goods traffic, I find that I can obtain an ample floor area with less dead weight than can be secured by any other width; *on a wider gauge the dead weight increases, on a narrower one the capacity diminishes.* A statement of the actual results of comparison will explain this more clearly and more quickly than could be done otherwise. On the Queensland 3 ft. 6 in. Railway, the composite passenger carriages are 6 ft. 6 in. wide and 6 ft. high inside. The capacity is equal to 34 persons, and the weight is 10 tons 5 cwt., or 6 cwt. per passenger; the second and third class carriages accommodate 48 persons, and weigh 9 tons 2 cwt., or 3.75 cwt. per passenger. The wagons average 14 ft. in length, 6 feet in width, and weigh 3 tons 5 cwt. The covered wagons are 6 feet high inside, and the open wagons have sides 30 in. high, the first would have a capacity of about 7 tons, the latter of about 5 tons, the respective proportions of paying load to weight being 2.15 to 1, and 1.54 to 1.

On the Norwegian 3 ft. 6 in. lines, the first-class carriages are 6 ft. 10 in. wide outside and 20 ft. long, weigh 4.6 tons, and carry 32 passengers, the proportion of weight per passenger being 2.9 cwt.; the second-class carriages have the same length and width, carry 32 persons, and weigh 2.4 cwt. per passenger. The covered goods wagons are 18 ft. long, 6 ft. 7 in. wide outside, weigh 3.7 tons, and carry 5 tons, the proportion of freight per ton weight of wagon being 1.2; this proportion is steadily maintained throughout the wagon stock, rising, however, as high as 1.6 to 1, while some of the more recent stock carries 6 tons instead of 5; of the increase of dead weight in these I have no data.

For a 3 ft. gauge, the stock that I construct is as follows: for first-class passengers the carriages are 18 ft. 6 in. long, 6 ft. 8 in. wide inside, seating 18 passengers, and weighing 3 tons 5 cwt., or 3.6 cwt. per passenger. For second-class, the carriages are 16 ft. 6 in. long, 6 ft. 8 in. wide, weighing 3 tons, and carrying 24 passengers, being 2.5 cwt. per passenger; the third-class carriages are of similar size, but seat 30 people, the dead weight being 2 cwt. per passenger. It will be noticed that these proportions are nearly identical with those on the Norwegian lines, but considerably less than those of the Queensland Railway.\* My open wagons are 10 ft. by 6 ft. 6 in. by 2 ft. 10½ in. high, weighing 28 cwt. 3 qrs., and having a cubic capacity of 4 tons, equal to a proportion of 3 to 1; also others for light goods, such as cotton, are 14 ft. by 6 ft. 6 in., with posts and rails 6 ft. 6 in. high from floor, or, as we are now running them in Mexico, with a low ledge running all round only 6 in. high, on which cotton bales are piled in a similar manner to that on a street wagon or Lorry and covered with tarpaulin. The covered wagons are 10 ft. by 6 ft. 6 in. by 6 ft., of 360 ft. contents, and weighing 33 cwt., equal to 3 tons of carrying capacity to 1 of dead load. In all this stock, as well as in the other classes required, the centre of gravity is kept low, and an angle of stability of 38° is in all cases maintained. It will thus be seen that upon a 3 ft. gauge I am enabled to place stock of ample size and of less weight than can be done on the 3 ft. 6 in. lines. In adopting this stock, I secure several advantages inseparable from the Fairlie gauge. The principal of these are: the reduced widths between the sole bars for the under frames of wagons and carriages, and lengths of wheel centres; these in turn affect the scantlings of material, the weight of the wheels, the size of axles, to carry certain loads. It has been argued that the excess of strength over the actual requirements for carrying, but necessary to resist the shocks and concussions incident upon shunting, &c., would not be affected by the gauge; and that if the gross weight of a train is maintained upon the narrow, that is now worked on the broad gauge, the wagon frame and couplings must be

\* The stock here described is on the type used in this country; a different type would require to be made to suit different tastes, as in America for instance, carriages should have a central passage and rest on two bogies or trucks, with entrances at each end.

alike in weight to give equal strength to withstand sudden shocks and strains. Of course this is in itself quite true, and certain parts must be as strong in a train of given weight on a narrow as on a broad gauge. The force of the argument falls to the ground, if we remember that under present circumstances an average goods train, say of 250 tons, has only 50 tons of paying weight, the remaining 200 tons being stock. Now, on the narrow gauge, supposing that only one ton of goods was carried per truck, as in the case of the 4 ft. 8½ in. gauge, the dead weight required to carry it on my system would be only 87½ tons, making the total weight little more than half, and reducing the force of shocks upon the train in a proportionate manner, so as consequently to reduce the requisite weight of parts. Take, now, this same weight of paying load in a train, namely, 50 tons, and place it in the same portions in the wagons of the Norwegian 3 ft. 6 in. line, or in those of the Queensland Railway, and we shall find that the dead load carried runs up to 185 tons, or a close approximation to our English practice. Probably, therefore, this stock as built is not too heavy to resist the strains and shocks thrown upon it by reason of its own weight; but by the mode of coupling employed on the Fairlie stock, the destruction arising from the shocks caused by sudden stopping and starting of the trains, especially when shunting, is entirely avoided, and as the strength and consequent weight of the present stock depends on the necessity of resisting these shocks and bumps, it follows that the instant these are removed, the necessity for all this extra strength and weight is removed also.

The foregoing figures really mean that to carry 50 tons of goods on the Norwegian or Queensland 3 ft. 6 in. gauge, the proportion of 1 ton per wagon being preserved, 92 per cent. of the weight of rolling stock used on the 4 ft. 8½ in. would be required; as against only 43 per cent. on a 3 ft. gauge; showing a saving of 47 per cent. on the latter as compared with the 3 ft. 6 in., as shown in the diagram. Of course, if the wagons were loaded up to full capacity, these percentages would be very much changed.

It is to this point especially that I wish to direct your attention, as upon it the economy of the 3 ft. gauge rests. Whatever saving may be effected in first cost may be lost sight of, the great advantage lying



in the saving effected in working expenses. *Every ton of dead weight saved goes towards securing the prosperity of the line*, and if we can obtain the ample platform which the 3 ft. gauge gives, combined with so much saving in weight, there is nothing left to be desired. In making my comparison, I have taken matters as they exist in Queensland and in Norway. The able engineers of those lines have designed their stock as economically as they found possible. I should have thought the dead weight might have been reduced to a certain degree; but of course I am aware that no such reduction as may be made on a 3 ft. gauge could be achieved.

Before I conclude, I may refer to one or two prevailing errors which exist with regard to the narrow gauge, and which are often urged against it. It is said that with a 3 ft. or 3 ft. 6 in. gauge, a far larger amount of siding and goods shed accommodation is required. Is it not sufficient to point out, as the wagons carrying the same amount on the latter as on a wide gauge are but some 10 ft. long as compared to 16 ft., that a train of the former, conveying the same loads as one on the latter, *would have but five-eighths of its length*? Here, again, the axiom of subdivision of traffic is applicable in all its force.

Again, a common notion—and one that was strongly urged when the discussion concerning India was in progress—is that narrow-gauge railways may be constructed in difficult and hilly countries, but not on level and favourable ground. Doubtless this idea has grown from the fact that the saving of construction in the former localities is greater than in the latter. But, as I have already stated, the economy in the cost of construction is altogether subordinate to the greater and constant economy in daily use. The fact is that narrow-gauge lines are useful everywhere, are needed everywhere; the saving in their first cost rises and falls with the country over which they pass, and, always considerable, is greatest where precipitous districts demand lines that creep around and up hill-sides; but the subsequent economy is not variable; it is always what I have shown it to be, when narrow-gauge railways and their equipments are worked, as everything should be worked, with a view to progress and development.

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FROM THE "TIMES," AUG. 7TH, 1871.

On Monday, August the 7th, the *Times*, in its report of the doings of the British Association, noticed the reading of this paper, and after giving long extracts from it, which it is unnecessary to repeat here, completed its notice of the discussion which followed the reading by the very important statement that General Strachey, head of the railway department for India, detailed certain facts which he had observed on the Festiniog and other narrow railways in India and elsewhere, *and expressed his entire concurrence with Mr. Fairlie as regards the economy and capacity of the narrow gauge.* He said that India was, as compared with England, a poor and an extensive country, requiring very long lines of railway on which there could as yet be only limited traffic. The Indian Government had no capital for the construction of railways, and could only make lines that would be self-supporting. They were, therefore, compelled to construct them in the cheapest manner compatible with efficiency, *and the problem thus presented to them had been effectually solved by the narrow gauge, which must, at no distant time, become the type of construction in India.*

THE END.

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